VALUE ADDING AND SUPPLY CHAIN DEVELOPMENT FOR FISHERIES AND AQUACULTURE PRODUCTS IN FIJI, SAMOA AND TONGA

Scoping study for Tilapia *(Oreochromis sp.)*

Australian Government
Australian Centre for International Agricultural Research

Institute of Marine Resources: Technical Report 04/2012

USP
FACULTY OF SCIENCE, TECHNOLOGY AND ENVIRONMENT
School of Marine Studies
Institute of Marine Resources

Value adding and supply chain development for fisheries and aquaculture products in Fiji, Samoa and Tonga: Scoping study for Tilapia (Oreochromis sp.)

Institute of Marine Resources
School of Marine Studies
Faculty of Science, Technology and Environment
University of the South Pacific

2011

Pacific Agribusiness Research and Development Initiative (PARDI) Project 2010/002:
Value adding and supply chain development for fisheries
and aquaculture products in Fiji, Samoa and Tonga

This publication should be cited as:

South, G.R., Morris, C., Bala, S. & Lober, M. 2012. *Value adding and supply chain development for fisheries and aquaculture products in Fiji, Samoa and Tonga: Scoping study for Tilapia (Oreochromis sp).* Suva, Fiji: Institute of Marine Resources, School of Marine Studies, FSTE, USP. IMR Technical Report 04/2012. 18pp.

Published by Institute of Marine Resources,
School of Marine Studies, FSTE, USP,
Private Mail Bag, Suva, Fiji.

ISBN: 978-982-9143-10-5

Cover photographs from left to right:

Lovell, E., 2008, *Porites cylindrical* coral off Suva waters, Fiji
Morris, C., 2008, Prawn harvest at Navua Farm, Fiji.
Morris, C., 2009, Tilapia harvest at Navua Farm, Fiji.
Miller, C., 2010, Spinner dolphin off Moon Reef, Dawasamu, Fiji.
Morris, C., 2011, *Caulerpa* at Tongan Market

Layout and Design: Dikoila A. Valemei

Printed by: University of the South Pacific

TABLE OF CONTENTS

INTRODUCTION

Tilapia, named the 'food fish of the 21st century', is one of the most cultured freshwater fish in the world, farmed in more than 100 countries (Norman-Lopez & Bjorndal, 2009). A hardy and prolific, fast-growing tropical fish, it requires low input during grow-out periods and can be farmed successfully on any level, from extensive to intensive culture in ponds, tanks or raceways (Fitzsimmons, 2006). It is disease resistant, tolerant of poor water quality, can eat a wide range of food types and be cultured in fresh or brackish water. Chemicals and antibiotics are not necessary for commercial farming (Fitzsimmons, 2008).

Integrated farming of crops (rice, poultry, sheep) with tilapia is a common practice in most parts of the world (El-Sayed, 2006). They are also used in aquaponics (integration of hydroponics and aquaculture), a system where fish and plants are grown together in a recirculation system. The plants (Rakocy et al., 2004) directly use nutrients produced by the fish culture system.

Tilapia production continues to rise with global production figures predicted to reach 3.7 million tonnes by the end of 2011 (http://www.globefish.org). The growth in this field has doubled per decade with global tilapia landing (capture and culture) at 515,000 tons in 1984, over 1 million tons in 1995 (Fitzsimmons, 2000) doubling to over 2 million tons in 2006. Asia is the largest producer of farmed tilapia, contributing 75% of the world's tilapia production (SEAFISH, 2011) with China being the main supplier, production reaching 250, 000 metric tons in the first ten months of 2010, 24% higher than the previous year, in spite of severe weather conditions. (http://www.globefish.org). The United States is the world's single largest tilapia importer, with imports totaling over 215,000 metric tons in 2010, at a value of USD$842 million (ERS, 2011).

Introduced into the Pacific Islands region in the 1950s, tilapia became a commodity for culture due to its low-cost and success in other regions. For Fiji and Samoa, tilapia was for human consumption and as potential pig feed (Costa- Pierce 1998), although in Tonga it became an unsuccessful attempt to control mosquitoes. Fiji and Papua New Guinea both have policies of government support for tilapia farming in rural areas. Household-scale tilapia farming is common in the Pacific but medium-scale enterprises are now on the increase (Pickering, 2009).

Pond culture is the main culture method used in the Pacific although cage culture in a lake is practised in Vanuatu. Integrated farming of tilapia with sheep, ducks and chicken is also practiced in Fiji, whereby the animal pen is built on top of the tilapia ponds, allowing waste to drop in the water and induce growth of primary producers (algae) which in turn are eaten by the fish. In addition, a few farmers practice polyculture of tilapia with carp and/or prawns.

VALUE-ADDING IN THE PACIFIC

The increasing demand for tilapia has also seen an increased number of value added products. In the 1980s, the only tilapia product in the international market was whole frozen forms, but with increasing demands, exporting countries started producing and exporting in increased quantity and quality (processed). The major tilapia producing countries produce tilapia as whole frozen, IQF fillets, fresh fillets and sashimi.

Case study 1: Tilapia by-products in the global market

By-products from tilapia are available on the global market. **Tilapia skin** is used for a variety of leather goods like purses, clothing and accessories (Fitzsimmons, 2006; Fitzsimmons, 2004). Several companies in Brazil use treated and dry tilapia skin to produce dresses, skirts, vests, wallets, purses and briefcases. Another possible market for tilapia skin is as a pharmaceutical product. Several European firms are purchasing frozen or salted skins which are processed for gelatin and used to make time-released medicines, substituting material from tilapia skins for mammalian products (Fitzsimmons, 2004). Another by-product is its **trimmings and heads** as heads are used for soups in some countries. Fillet trimmings and throat meat can be recovered and used for ceviche and other preparations using small amounts of fish. Equipment also exists to facilitate the recovery of flesh through **de-boning of skeletons**. The flesh recovered provides a base for fish sticks, fish sausage, fish balls, fish sauce or other highly-processed forms. Carcasses, heads, and trimmings are also used for animal feeds (Fitzsimmons, 2004). A cottage industry in Brazil is using **dry and curled tilapia scales** to make ornaments, such as flowers (Fitzsimmons, 2004) and a study by Dale *et al*., (2004) looked at the possibility of using **tilapia meal** as a feed ingredient for animals such as poultry. Tilapia meal has been shown to have as high as 57.8% crude protein level.

The United States is one of the major importers in tilapia products and the product range includes fillet of different sizes (3-5 oz, 4-6oz, 5-7oz, 6-8oz etc) and packages; with skin off or on; deep skinned; ozone-dipped; carbon monoxide treated; individually quick frozen; smoked; liquid smoked and in sashimi grade (Fitzsimmons, 2004; Lim and Webster 2006). Individually frozen whole fish can be either marketed in individual plastic bags or individual Styrofoam trays with plastic wrap for retail sales. Similar options are available for fresh or frozen fillets.

Most fillets now also go through hand trimming with the dorsal and ventral margins trimmed off leaving nicely rounded edges and a smooth appearance. Fitzsimmons (2004) noted that many processing plants ran their trimmed fillets through a water bath after trimming and whereas in the past, some plants used a mild chlorine solution to reduce bacteria and lengthen shelf life, nowadays, most plants use ozone gas, which is bubbled into the tank. Ozone treated fillets are not subject to the disinfection byproducts that chlorine can form with organic molecules nor does it leave any disagreeable taste that can be discerned by some consumers. “Most plants use an on-site ozone generation system that supplies the small amounts of ozone needed to effectively disinfect fillets. Studies conducted at the University of Arizona demonstrated that bacterial counts could be lowered by several degrees of magnitude and shelf life could be extended by several days when fillets were rinsed with ozonated water compared to untreated fillets” (p6).

Tilapia skin is also sold on the international market as frozen or in salted and deep fried forms. In Thailand and the Philippines, skins are scaled, cut into thin strips and deep-fried, as appetizers served with a slice of onion and cut lime (Fitzsimmons, 2004).

Efforts in value adding of tilapia have been minimal in the Pacific (www.spc.int). Tilapia is mostly sold live or fresh in bundles but interestingly in Papua New Guinea, cooked tilapia (fried) is sold on the roadsides (Ponia & Mobiha, 2002). Simple village level post harvest processing, such as smoking may exist in some countries (www.spc.int) but proper documentation is absent.

FIJI

In Fiji, Tilapia (*Oreochromis mossambicus*) was initially kept in Nacocolevu Agriculture Station in Sigatoka (Nandlal & Foscarini, 1990; www.spc.int) but was later released into the natural river systems with some earthen ponds being stocked with Tilapia. Over the years, Tilapia became quite popular amongst the inland people of Fiji (Nandlal & Foscarini, 1990) and with it, the

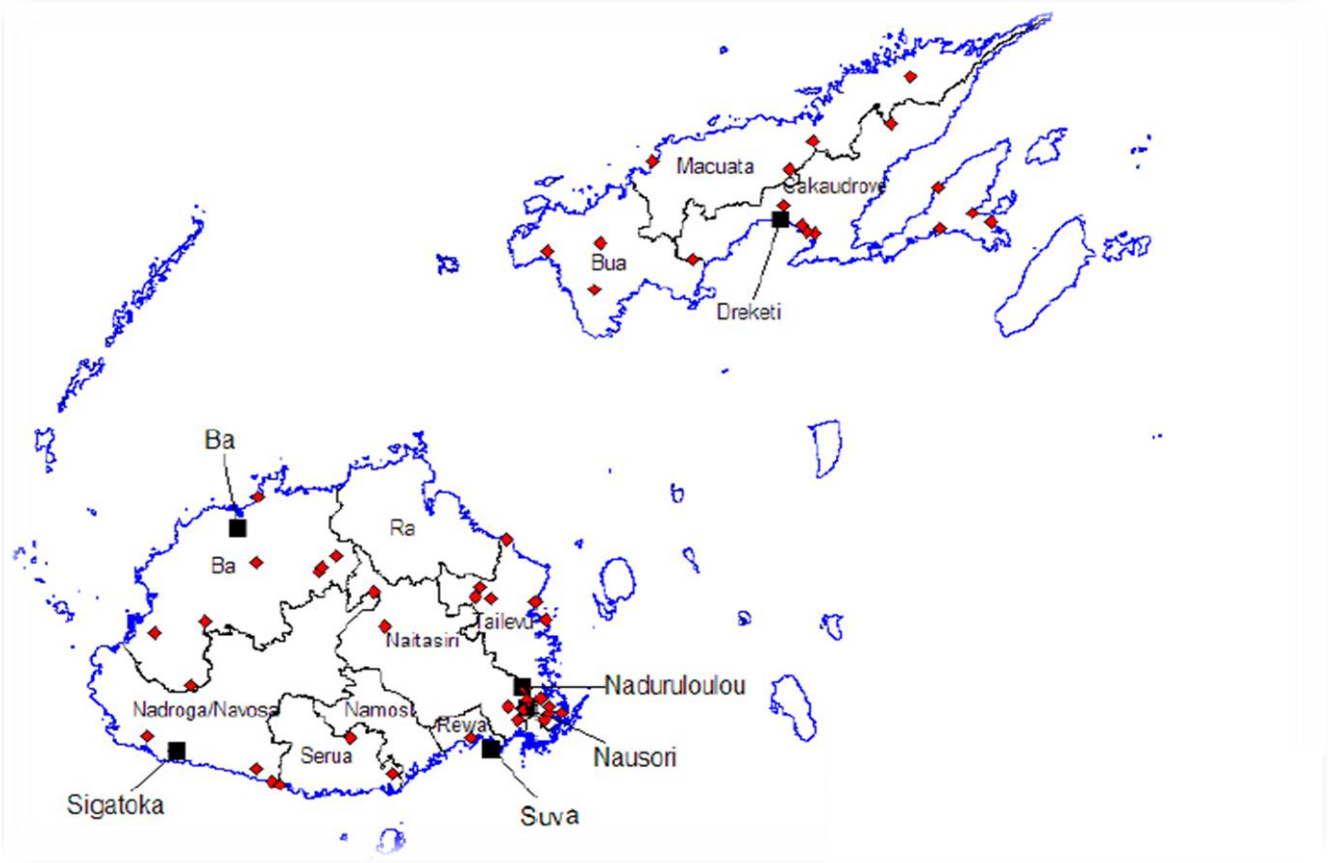

Fig. 1: Map of Fiji showing the distribution of tilapia farms (red diamond) and major markets (black box)

potential for aquaculture. The freshwater aquaculture station at Naduruloulou was established in 1975 and ACIAR funded research and development of tilapia during the period 1993 to 2000. Several introductions of a better performing species (*Oreochromis niloticus*) and strains were introduced and a better performing strain was obtained and helped small-scale Fijian farmers improve the productivity and profitability of tilapia farming. The Fiji Fisheries Department has assisted other Pacific Island countries develop and improve tilapia farming through the training of fisheries officers and the supply of fry.

Currently tilapia is found in most major rivers systems of Fiji as well as some outer islands. There are approximately 300 tilapia farmers around Fiji (Figure 1), out of which 50 are commercial farmers, the rest being semi-commercial (100) and subsistence (150); *(Source: Presentation by Principle Aquaculture officer, Commodity Task Force meeting, 2010)*. Estimated annual tilapia production recorded 284.9 tons in 2007 and 182.3 tons in 2008, valued at FJ$1.4 million and FJ$0.9 million respectively (Fisheries Annual Report, 2007 & 2008). Tilapia currently sells for FJ$5-6 per kilogram.

Fish processing and quality standards in Fiji are in place and the same protocols can be adopted for future tilapia processing/value adding. The Fiji Fisheries Department has a Product Development and Utilization (PDU) unit, which assists fish processers (such as Fiji Fish, Golden Ocean Fish, Tosa Bussan Fiji, Solander Pacific, Tripacific Marine, Celtrock Holdings etc) achieve quality products of international standards for local and export markets. These standards include, the European Union Food Safety, United States Food and Drug Administration, and Hazard Analysis and Critical Control Points (Fisheries Annual Report 2008). Processing companies process deep sea fish such as tuna (yellowfin, bigeye

Case Study 2: Nadala women learn new skills in fish farming

"Women in rural areas are known for their skills and talents in making use of natural resources to earn a living for their families. An inspiring story is unveiled in Driti Village in the Tikina of Dama where women have taken the lead role in managing six fish ponds that is a source of income and most importantly supplements the protein intake villagers desperately lack in their daily diet. Established in 2002 by the Department of Fisheries, Ministry of Women, Secretariat of the Pacific Community and University of the South Pacific Marine Studies the project was handed over to Driti women. Known as the Seatura Women's Club Aquaculture project the two main objectives met by the initiative are: Create source of income for the women and sustain their nutrition level.

According to Seatura Women's Club leader Narieta Leba about 40 women benefit from the project and the revenue earned is deposited into a fixed savings account while portion of the money is used to meet miscellaneous expenses. "Most of the money is kept in the bank for education purposes of the children in the village and in total from the fish project and the honey the women have managed to save a total of $26,000 in the savings account. During the harvest we are able to earn $1000 to $2000 a month," said Leba. She said the fish was supplied to the nearby villages and Bua School at reasonable prices and there were plans to expand the market to Labasa Town." (http://www.connectme.com.fj/news/national/Womenthrive-in-Fish-Pond-business) on: 16/03/11

and albacore), marlin, sword fish etc. Fish are exported fresh or frozen, whole gilled & gutted, headed gilled & gutted. These companies also vacuum pack fresh and/or frozen loins and steaks. High quality chilled and processed tuna are also exported to Japan, Europe and United States. Two companies, PAFCO and Voko Industries are involved in canning (FTIB, 2009).

In a case study by Prasad (2006), fishing contributed about 2.4% to Fiji's GDP in 2001 however, this does not provide the whole picture as fish processing and post harvest activities are considered within other sectors of Fiji's economy. Summarized data from the Fiji Bureau of Statistics indicates that export of fishery products account for approximately 9% of the total domestic export from Fiji.

Marketing

The Tebara Meats (previously Dairy Farms Fiji Limited) aquaculture unit in Fiji sells it frozen. Value-adding has been conducted on an experimental basis by some University of the South Pacific (USP) staff and students and a businessman does small-scale tilapia smoking but village-level smoking also exists. Terry Mandam runs a small family business and has been selling smoked fish including tilapia since 1985. He buys live tilapia from the Nausori market (FJD5.00 for 4 fish), smokes, vacuum packs and sells them for FJD12.00. Mandam cold smokes (30-40 °C) tilapia on order or for research purposes. The smoker used is homemade (made using a 44 gallon drum) and the design can be adopted by farmers at minimal cost. Fish are gilled, gutted, scaled and brined; followed by a quick freshwater dip and fan drying (Figure 4). Prior to fan drying, a small stick is used to open the stomach of each fish. Once dried, the fish are hung on metal rods and placed vertically in the smoker. The whole process from brining to the smoked product takes approximately 8 hours. The smoked fish are then cooled, vacuum packed and stored in a freezer until it is ready to be cooked. Mandam believes that value adding of tilapia has great potential in Fiji and needs to be taken to a commercial level.

Consumption

In Fiji, the major consumers of tilapia are indigenous Fijians while Chinese and Indo-Fijians purchase tilapia at a smaller scale from the municipal markets. These prefer to buy live, plate size tilapia, that is, 4-6 fish per kilogram. Indigenous Fijians do not prefer larger-sized fish (2-3 per kg) as smaller fish allows each member in the family to have one whole fish per plate.

FIGURE 2: PROCESS OF COLD SMOKING TILAPIA: A)BRINING; B)OPENING THE INSIDE; C)DRYING PRIOR TO SMOKING; D)SMOKING AND E)VACUUM PACKED FINISHED PRODUCT (PHOTOS: TERRY MANDAM)

FIGURE 2A: A SIMPLE DRUM OVEN DESIGNED AND USED FOR COLD SMOKING TILAPIA

Figure 2: Map of Samoa showing the semi-commercial farm sites on Upolu

There are no hotels or restaurants that are known to purchase tilapia however, consumer/market testing can be done once value-added tilapia products are available and introduced into the local markets.

SAMOA

In Samoa, Tilapia (*O. mossambicus*) was introduced in 1955 (Bell *et al.* 1997; www.spc.int), after its potential as a candidate for pond culture was investigated by SPC (www.spc.int). Following this, the Fisheries Division of Samoa introduced a better performing *O. niloticus* for aquaculture, under its South Pacific Aquaculture Development Project (SPADP), in 1991. Tilapia has been a subsistence fishery in a few villages, but utilized at a larger scale in Savaii (Bell *et al.,* 1997). They have been released in main freshwater river systems in Savaii for subsistence (www.spc.int). In 1996, several demonstration ponds were constructed under the SPADP and Fisheries Division (Nandlal, 1996). By late 2000, Samoa had 19 tilapia farms in total, 11 on Upolu and 8 on Savaii (Su'a *et al*., 2009).

Figure 3: Tilapia cement pond, EFKS, Samoa (Photo: Falese'ela Lefaga)

Figure 4: Earthen ponds at one of the commercial freshwater farms in Fiji (Photo: Avinash Singh)

Marketing

Currently, there are approximately 29 farmers out of which 5 are semi-commercial and 24 are subsistence. Annual production from 4 semi-commercial farms located at Vailele, Falese'ela (Figure 2) and Falelauniu (on Upolu Island) is conservatively estimated at 862 kg.

In addition to these farms, 3 communities harvest tilapia from natural water bodies. These are communities of Faleapuna and Saoluafa-ta on Upolu and Satoa-lepai on Savaii Island. These fishermen use nets and spears for tilapia, crabs and eels for the family meal. On a good fishing trip, there can be 20 tilapia caught but on average 4 - 5 tilapia were caught per week ranging from 0.8 to 2 kg in size.

Consumption

A taste study of smoked tilapia in Samoa showed that some people (33%) preferred smoked tilapia over smoked reef fish (Bell *et al.,* 1997), which suggests that fish smoking (tilapia and other species) is being practiced. Generally, there is no value adding of tilapia in Samoa.

The major consumers of tilapia are the locals while expatriate Asians and Africans have also been reported buying tilapia from one of the farms. Chinese restaurant owners in Samoa usually bought for restaurant menus and for their own consumption. The communities of Saoluafata and Faleapuna on Upolu Island and Satoalepai in Savaii Island who are involved in the tilapia fishery consider tilapia as a staple protein source especially in the latter where tilapia strings were sold along the roadside.

Case Study 3: MSc research on "Value-addition of *Oreochromis niloticus* (Tilapia)"

While a great deal is known of the socio-economic aspects of Tilapia, little has been done on product enhancement. A current MSc research at USP by Janice Natasha is looking at the value-adding of Tilapia, a fisheries commodity in Fiji. The demand is extensive but it is being sold live only in the local markets. However, most consumers do not prefer Tilapia because of its characteristic tasteless meat. This project proposes to investigate possible product enhancement methods that can be used at the community level and for potential commercialization such as the salting of Tilapia as a pre-treatment to further product enhancement such as drying, smoking, freezing and canning.

TONGA

In Tonga, the aquaculture of tilapia is nonexistent. Initially, in the 1950s tilapia (*Oreochromis mossambicus*) was introduced in an unsuccessful attempt to control mosquitoes. The culture of tilapia, integrated with piggery was later trialed at Sopu with unsuccessful results. Tilapia is believed to have spread to neighboring areas and also introduced to several outer islands in Tonga during this time (www.spc.int) but there are no records of tilapia fishery. The "Tonga Aquaculture Commodity Development Plan 2010-2014" has identified commodities but Tilapia is not on the priority list, being considered as having medium importance and impact.

According to the Fisheries Aquaculture Officer, there has been some interest in the subsistence production of tilapia and farming tilapia for pig food. Tilapia exists in estuarine waters in the lagoons and lakes in Tongatapu, Vavau, 'Eua and Ha'apai and grow to a large size (individuals are likely to be in the range of 800g to 1kg). On the island of 'Eua, there is no intertidal area and tilapia is a major protein source for the residents who harvest it from the lake. However, tilapia may be given higher priority in the future given the decline in inshore fisheries and the high cost of living (*Personnel Communication, Poasi Ngaluafe, April, 2011*).

PRELIMINARY ANALYSIS OF THE SUPPLY CHAIN

FIGURE 2: SELLING OF LIVE TILAPIA AT NAUSORI MARKET. TOP L AND R: TEMPORARY HOLDING TANKS FOR LIVE SALES OF TILAPIA; BOTTOM L AND R: SCOOPING AND CHOOSING OF FISH BY CUSTOMERS

In **Fiji**, the market/supply chain occurs over a 4 - 6 month cycle as such:

1. Farm-based harvesting (partial or complete) with assistance from Fisheries Department
2. Transport to the market live in tanks or alternately sold live to consumers from the farm
3. Sale of live fish in municipal markets on Saturdays to consumers
4. Consumption by non-commercial users

The cash flow steps for Fiji are:

1. Transportation and related costs to the market
2. Percentage loss of product due to handling (mortality)
3. Purchase price of tilapia to farmers
4. Income to farmers

In **Samoa**, the Savaii and Upolu market/supply chain occurs over a 6 - 12 month cycle as follows:

1. Farm-based harvesting (partial or complete) with assistance from Fisheries Department
2. a. Product sold live (and occasionally gutted and scaled) to consumers from the farm or
   b. transported to restaurants for sale or
   c. transported to municipal markets and sold live to consumers on Saturdays
3. Consumption by non-commercial and commercial users

Tilapia production and growth rates

Statistical data on tilapia production and growth is very hard to come by as farmers do not record their production. However, Fisheries Division is training local tilapia farmers to take simple recordings of their daily operations, as the information is vital for their development if they wish to expand or commercialize.

A total of 8,034 tilapia fingerlings were distributed to 8 new farmers (7 in Upolu and 1 in Savaii) and restocking of 18 existing farms in Upolu. Overall an average size of 9 cm fingerlings was distributed at an estimated weight of 9.5 g, presuming the estimated tilapia produced and distributed at this fiscal year (2010 – 2011) will be 886.97 kg.

Quarterly monitoring of stocked farms calculated an average growth of tilapia at 1.24cm/month or 105g/month and an annual survival rate of 85%. Thus estimation when harvested will be expected for the stocks to reach average size of 18 cm or average weight of 750 g, thus a total weight of harvested stocks with an 85 % will be 51,217.5 kg or 51 tonnes.

Source: Fisheries Division, Ministry of Agriculture and Fisheries, Apia, Samoa. March 2011

Case Study 5: The cost structure of tilapia farming in Samoa based on an average pond size of 5 x 10 (m)

Capital involves machinery to clear land if it's new land for the pond(s). Construction of ponds and plumbing are the other two main factors required for tilapia farming.

1. **Labour:**
   Worker wages are not counted since tilapia farm management is usually a family activity. However when there is harvesting, depending on the catch, this is distributed to neighbors, relatives and to those who assisted in the farming or harvesting.
2. **Operating Expenses:**
   For subsistence farmers, the main operational cost is feed. The main use of fuel on the farm is mowing grass, transporting of feed to the farm or cutting down nearby trees threatening pond stability and shading over the ponds.
3. **Purchase of Fingerlings:**
   Ministry of Agriculture and Fisheries- Fisheries Division (FD) is the main supplier of tilapia fingerlings to the local tilapia farmers. Currently the fingerlings are free of charge for initial stocking. If the industry expands, there will be a need for the FD hatchery to expand to meet the demand and set prices to sell fingerlings.
4. **Feeds:**
   The feed currently used by the FD is a combination of fish meal, coconut meal and brewery waste from Vailima Brewery Company. The pellet machine has enabled the production of pellets for feed now sold at $3/kg. Fisheries had assisted Farmtech Company Limited in producing the same feed using the FD's formulation. The formulation has been modified by the company replacing the brewery waste with the mashed cassava. Most of the tilapia farmers in Samoa farm for food security and are advised to utilize pele and cassava leaves that are readily available.
5. **Marketing**
   Tilapia in Samoa is mainly consumed by the subsistence market. However past trials of tilapia sales at the Apia Fish Market has been successful at $5/kg. Future opportunities lie in the potential export of tilapia. In 2009 a tilapia farm was established at Vailele by business man, Sala Vaimili. The pond is fed with water diverted from the river adjacent to the farmer's land. The pond size is estimated at 96 m^2. The pond was initially stocked with 3000 fingerlings with total weight of 39kg. After 8 months of culture, 1980 fish (600 kg) were harvested. As it was Vaimili's first tilapia harvest, it was distributed to his relatives and friends.
6. **Risk Analysis**
   Using the model developed by AusAID project in 2005, we can assume that the risks (natural disasters, theft, disease, lack of fry supply) for a typical tilapia farm range between a probability of 10-40%.

Source: Fisheries Division, Ministry of Agriculture and Fisheries, Apia, Samoa. March 2011

REFERENCES

Bell, L. Fainuulelei, P. Lindsay, S. Mulipola, A. & Taualofa, P. (1999). *Nile Tilapia in Samoa Production, Distribution and Monitoring.* Apia, Samoa: AuSAID and Samoa Fisheries Project.

Bell, L., Mulipola, A., Skelton, P., Sasi, T., Matsunaga, Y. & Alefaio, F. (1997). *Comparative taste study on Nile Tilapia (Oreochromis niloticus) and marine fish in Samoa and Nauru.* FAO field document No. 3/1997.

Costa-Pierce, B. (1998). A *market-driven, social ecological approach to planning for tilapia aquaculture development in Fiji*. (Unpublished Report)

Dale, N.M., Zumbado, M., Gernat, A.G. & Romo, G. (2004). Nutrient value of tilapia meal. *Journal of Appl. Poult. Res 13*: 370-372.

El-Sayed, A.M. (2006) *Tilapia culture*. A.-F.M. El- Sayed 2006. CABI Publishing.

Economic Research Service (ERS), USDA (2010). *Aquaculture Data.* (http://www.ers.usda.gov/data/aquaculture/TilapiaImportsValue.htm)

Fisheries Annual Report. (2007). Fiji- Department of Fisheries, Ministry of Fisheries and Forests, Parliamentary paper No. 38/08

Fisheries Annual Report. (2008). Fiji- Department of Fisheries, Ministry of Fisheries and Forests

Fisheries Division Annual Report for the Fiscal Year 2009- 2010. (2010). Samoa- Fisheries Division, Ministry of Agriculture and Fisheries

Fitzsimmons, K. (2000). *Future trends of tilapia aquaculture in the Americas*, pp. 252-264. In: B.A., Costa-Piere and J.T., Rakocy, (eds). Tilapia aquaculture in the Americas, Vol. 2. Baton Rouge, Louisiana, US: The world aquaculture society.

Fitzsimmons, K. (2004). *Development of new products and markets for the global tilapia trade*. Proceedings of the 6th International Symposium on Tilapia in Aquaculture, 2004, Manila, Philippines: 624-633.

Fitzsimmons, K. (2006). *Prospects and potential for global production*, pp. 51-72. In: C. Lim & C.D., Webster (eds). Tilapia biology, culture and nutrition. NY: Food Products Press & Haworth Press.

FTIB. (2009). *Investment opportunities in processed fish, fish products and processed seafood industry*. Suva: Fiji Islands Trade and Investment Board.

Johnston, B. (2005). *Economic Evaluation of Aquaculture Opportunities in Samoa.* Apia, Samoa: Department of Primary Industries and Fisheries. (Report for a Joint Samoa Fisheries and AUS AID Project)

Lim, C. & Webster, C.D. (eds). (2006). *Tilapia biology, culture and nutrition*. NY: Food Products Press & Haworth Press: 1-49.

Nandlal, S. & Foscarini, R. (1990). *Introduction of tilapia species and constraints to tilapia farming in Fiji*. Suva: South Pacific Aquaculture Development Project; FAO Project Report AC295/E. 23pp

Nandlal, S. (1996). *Report on tilapia demonstration farm in Western Samoa*. Apia, Samoa: Samoa Fisheries Department & FAO's South Pacific Aquaculture Development Project

Nandlal, S. & Pickering, T. (2004a). *Tilapia fish farming in the Pacific Island Countries. Volume 1. Tilapia hatchery operations*. Noumea, New Caledonia: Secretariat of the Pacific Community

Nandlal, S. & Pickering, T. (2004b). *Tilapia fish farming in Pacific Island countries*. *Volume 2. Tilapia grow-out in ponds*. Noumea, New Caledonia: Secretariat of the Pacific Community

Norman-Lopez, A. & Bjorndal, T. (2009). *The global market for tilapia-one or several*. Institute of Research Economics and Business Administration, Bergen. SNF Project No. 5716; working paper no. 10/09.

Pompa, T.J. & Lovshin, L.L. (1995). *Worldwide prospects for commercial production of tilapia*. Auburn University, Alabama: International Center for Aquaculture and Aquactic Environment, Department of Fisheries and Allied Aquacultures

Ponia, B. & Mobiha, A. (2002). Aquaculture in Papua New Guinea. Noumea, New Caledonia: Secretariat of the Pacific Community. *Fisheries Newsletter #101*, April/June 2002

Prasad, B.C. (2006). Trade *and environment dimensions in the food and food processing industries in Asia and the Pacific: a country case study of Fiji*. Suva, Fiji: Faculty of Business and Economics, University of the South Pacific

Rakocy, J.E., Bailey, D.S., Shultz, R.C. & Thoman, E.S. (2004). *Update on tilapia and vegetable production in the UVI aquaponics system*. Agriculture Experiment Station, University of Virgin Islands, USA.

SEAFISH (2011) *Responsible sourcing guide: Tilapia.* Seafish, Grimsby, UK. (http://www.seafish.org/media/publications/SeafishResponsibleSourcingGuide_tilapia_201107.pdf)

Su'a, T., Nandlal, S. & Hair, C. (2009). *Experimental stocking and community management of tilapia in Lake Satoalepai, Samoa*. Noumea, New Caledonia: Secretariat of the Pacific Communities. (Final report for mini project MS0604)

Teri, J. & Pickering, T. (2009). *Productivity and constraints in tilapia fish and freshwater prawn aquaculture in Fiji*. Noumea, New Caledonia: Secretariat of the Pacific Communities. Final report MS0507

SPC & Tonga-Ministry of Fisheries. (2010). *Tonga Aquaculture Commodity Development Plan 2010-2014* (2010). Noumea, New Caledonia: Ministry of Fisheries and Secretariat of the Pacific Community

RELEVANT WEBSITES

http://ag.arizona.edu/azaqua/ista/nutrition.htm

http://www.ers.usda.gov/data/aquaculture/TilapiaImportsValue.htm

http://www.lib.utexas.edu/maps/samoa.html

http://www.globefish.org

http://www.connectme.com.fj/news/national/Women-thrive-in-Fish-Pond-business

http://www.lib.utexas.edu/maps/samoa.html

http://www.seafish.org/media/publications/SeafishResponsibleSourcingGuide_tilapia_201107.pdf

http://www.spc.int

INSTITUTE OF MARINE RESOURCES (IMR)

IMR provides scientific and technical skills, capacity-building, marine resource assessments, coral reef monitoring/ database maintenance and socio-economic analysis for fisheries and aquaculture. IMR aims to increase the regional capacity to sustainably develop its marine resources through applied research, training and teaching. Research and development projects focus on marine ecology, aquaculture and biodiversity issues.

Much of IMR's work is externally-funded research and consultancies on the region's marine environment and its resources. Current activities centre on coral reef monitoring, marine biodiversity assessment, aquaculture management and cetacean research. The Institute also coordinates the South-West Pacific node of the Global Coral Reef Monitoring Network (www.GCRMN.org).

CONTACT DETAILS

Phone: 323 2930/ 323 2988
Fax: 323 1526

Website: www.usp.ac.fj/imr

Email: joeli.veitayaki@usp.ac.fj OR cherie.morris@usp.ac.fj

USP
FACULTY OF SCIENCE, TECHNOLOGY AND ENVIRONMENT

School of Marine Studies
Institute of Marine Resources